Robot is best to play with human!*

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***Abstract*— In this paper we present StimCards: an interactive game for cognitive training exercises. To increase the impact of this game we experiment four kinds of interfaces: a basic computer, an embodied conversational agent and a robot with two different appearances. The report of these experiments shows that the robot is the best positive feedback for cognitive game.**

I. Introduction

Nowadays there is growing concern about people with cognitive troubles. Their cognitive capabilities should be improved to protect their life quality as long as possible with cognitive stimulation, cognitive training and cognitive rehabilitation [1]. Informatics helps to practice this kind of activities. Cognitive training can be completely automated. People can work independently. To be efficient, this computer system should deal with acceptability, lassitude feelings and loss of attention.

Acceptability is the first problem to consider because it appears when people are introduced to new technologies. The elderly are generally the most reluctant to use computers because computers should not replace real people. In their mind, loneliness is the worst for feelings. They need to feel helpful, to improve their mind and to stay connected to other people [2]. Acceptability is not linked to social skills [3] or to computers knowledge. A study [4] showed that people with Alzheimer's learnt how to interact with computers, although they never used it before. They even gain advantage from that if computers allow them to practice training exercises and communicate with their family and doctors. Imbeault [5] specifies that games which combine training exercises and technology give more pleasure that paper games.

Games seem therefore a good solution to do cognitive training because they give cognitive profit ensuring that gamers enjoy themselves without making any effort [6]. Moreover games are interesting for their learning process, often used in education [7]. If game can solve the acceptability problem, there are two problems left: lassitude feeling and loss of attention. A study from Lazar [8] showed that passivity can cause lassitude feeling and loss of attention. To avoid people passivity, the computing system has to take human into account. People should actively contribute to the task and get an immediate positive feedback about their participation. In the Human-Computer Interaction domain, Goth showed [9] that it is the end of Graphical User Interface (GUI) because users are too passive. The system combining mouth and keyboard disappears. It is replaced by new applications with more natural interaction, that is: multimodal [10].

An efficient game should respect the Natural User Interface (NUI) considerations [9]. The question is to know how to create such a game in order to maximize its impact [11]. The game we built is guided by users. We tested several "human-game" interfaces (HGI): a GUI, an embodied conversational agent and a robot (with two different appearances). The experimentation objective was to test our game acceptability and to determine what kind of "human-game" interface is the most impacting for a training game.

Chapter II shows a list of research studies about games. Chapter III introduces our game StimCards. Chapter IV presents the four environments we compared in our experimentation. Chapter V details our experimentation which makes the conclusion that the robot is the best training cognitive game partner. Chapter VI gives conclusion and perspectives.

II. Solutions of today

Table I shows a list of research studies about cognitive stimulation or reeducation games. They can be classified according to their technology or according to target people. Generally, these games are specialized and can not be adapted to other domains. Five out of the six more current games are GUI although the community [9][10] showed that they might be NUI.

Some others games – that do no use computer – cause acceptability problems. ZPLAY [12] requires that patients wear sensor in order to supervise their health. This kind of systems is too invasive. New technologies should be transparently integrated [13] in existing systems to avoid a long learning period of time. Jecripe application [6] asks gamers to make movements or to mimic an avatar. It is a first step toward NUI. The problem is that the application does not take gamer actions into account, although "the human should be at the core of the system" [14]. Only a few games innovate with their technology: mobile peripherals, bike, augmented reality, game consoles. But these games are too specialized and closed. It is not possible to adapt them to others contexts.

TABLE I. Current cognitive games

Name	Year	Target domain	Technology
Story Mahsup [15]	2007	Everyone	Mobiles + PC
No name [16]	2007	Alzheimer	Bike + PC
No name [17]	2009	Cognitive troubles	Robot
Jecripe [6]	2010	Down syndrome	Computer
ZPLAY [12]	2010	Alzheimer	Computer + skin sensors
No name [18]	2010	Elderly	Augmented reality + tangram

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Name	Year	Target domain	Technology
VI-Tennis [19]	2010	Blind	Sound + vibration (WII)
No name [20]	2011	People with disabilities	Computer 3D character
SAVION [4]	2011	Dementia	3D
No name [5]	2011	Alzheimer	Computer
No name [21]	2011	Cognitive difficulties	Computer
No name [22]	2011	Amblyopia	Ipod Touch
No name [23]	2011	Cognitive troubles	Computer

These limitations suggest that an open game might be created. It should be adaptable to other domains and as many people as possible. To answer this objective, we created StimCards, which combines technology and card game. We designed it to be "all publics". Some experiments have to check this hypothesis. This paper presents the young public. The game is completely configurable and takes place in NUI domain.

III. StimCards

A. Equipment

StimCards is an interactive card game (see Fig. 1.) The elements of the game are: card with barcode (a QR code) on the verso, a camera, a computer and a tactile tablet. To play, gamers must put a card in front of the camera which recognizes the card and displays its environment in StimCards GUI as shown in Fig. 2. We developed a QR code reader based on a free library. The problem is that recognition capabilities are limited. So, we encoded only the question number in the QR code. When the program decodes this number, it reads a file which makes the link between question number and an associated XML file which contains question data (see III.B). Gamers give their answer with the tactile tablet. Others digital devices can be added to the game, such as avatars or robots. Fig. 1. shows an interaction example with a small humanoid robot and a Nabaztag.

Figure 1. StimCards, the interactive game

B. Game configuration

StimCards can be adapted with others questions. People only have to change the card file description. Each card is associated to a XML file which contains: the question label and associated picture, question type (multiple choice question, open question …), a card category (entertainment, sciences, math …), GUI background color, font color, a set of clues which can help gamers, a set of suggested answers (text and/or picture) and the true answer. These data are displayed in StimCards GUI. Fig. 2. shows an example of a loaded card.

Figure 2. A loaded card example in StimCards GUI

C. Game dynamic

The game sequences are not permanent. StimCards is created with MICE [24]. It is a computing modular environment which allows digital devices to communicate altogether. New module integration is easy and fast. Interaction scenarios are creating with a visual programming GUI. Thus, StimCards is configurable in two ways: it is possible to create new cards and to describe the game sequences.

1) Game example

In order to study StimCards acceptability, we created a simple scenario, tested with four different "human-game" interfaces (HGI): a computer, an ECA and a robot with two different appearances. In the interaction beginning, the HGI introduced itself. Then, it explains the game rules. It is mental arithmetic game[1]. There are five difficulty levels: light-yellow (most easy), dark yellow, light-green, dark green and blue (most difficult). The HGI asks the gamer to show a card to the camera. Gamer has one minute to react. If the time is out or if the gamer shows an inappropriate card, the HGI remind instructions. If the card is correct, the question is displayed on the StimCards GUI. In the same time, the HGI asks the question. Gamer has one minute to answer the question. If the answer is correct, game levels up. But if the time is out or if the gamer gives a wrong answer, the level does not evolve.

2) Scenario building with MICE

Fig. 3. shows the scenario which was creating with MICE. It is a state automaton, where states represent a game stage. For example, the I state corresponds to the HGI asking the gamer to show a card to the camera. If an appropriate card is detected, the current state is J, where the question is asked by the HGI. Orange states represent alternative situations. One possible alternative is the reaction after sixty seconds without any action or after a wrong card or a wrong answer. The K state is the moment when the HGI congratulates the gamer. Then, the HGI asks the gamer to show a new card and current game is I. After nine iterations,

(1) built with teachers from school which participated to the experiment.

game is complete and activates L state. The HGI thanks the human for the game.

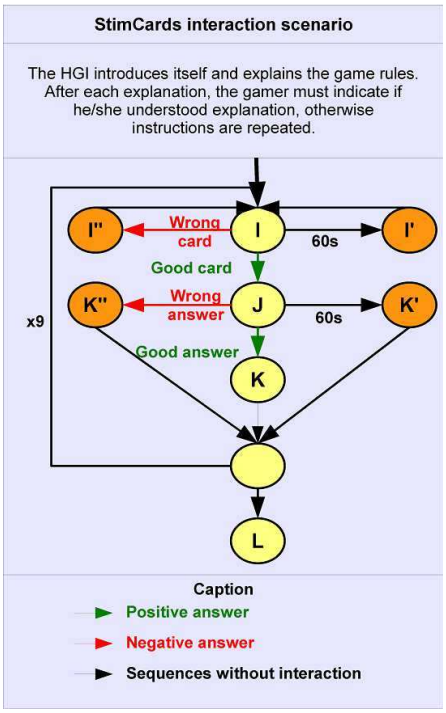

Figure 3. StimCards interaction scenario

Game stage or sequences can be easily changed by creating a new StimCards scenario.

IV. The four compared environment

Fig. 4. shows the four environments which were tested during experimentation and which are described below.

Environment 1: This environment corresponds to the A picture. It is the « computer » HGI. In this case, the environment is composed of a computer which displays StimCards GUI and a camera visual control. There are two external sound speakers.

Environment 2: This environment corresponds to the B picture. It is the "character" HGI. It is the same environment than the first one except that an avatar is added. This avatar, which is Greta [25], is screened on a scale of 1:1. Speakers are hidden behind the screen.

Environment 3: This environment corresponds to the C picture. It is the "robot" HGI. It is the same environment than the first one except that a small humanoid robot, called Bioloïd [26], is added. Speakers are located on both robot sides.

Environment 4: This environment corresponds to the D picture. It is the "animal" HGI. It is the same environment than the third one except that the robot is dressed up as a "cartoon chicken". The fabric is soft, like stuffed animal.

We tested two different robots to determine if the robot appearance has an incidence for interaction.

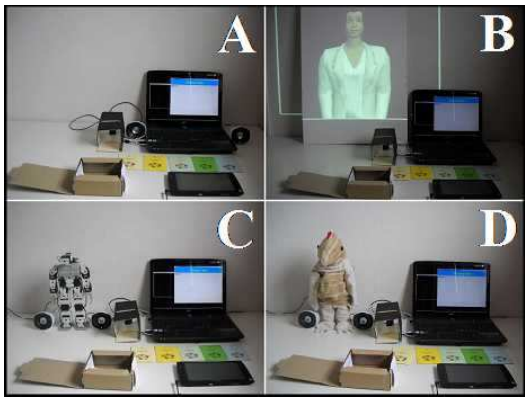

Figure 4. The four compared HGI

V. Experimentation

Our global objective is to check if StimCards is "all publics" and to determine which kinds of digital objects can ensure the best human-game interaction. This experimentation was a part of our global objective. There were two objectives. First, StimCards was tested in order to check its usability and acceptability with children. Second, four different Human-Game Interfaces (HGI) were tested in order to determine children favourite one. The experimentation was composed of four sessions which lasted ten minutes. There was one session per environment, during two weeks (two schools). Each participant interacted with the four environments. Each HGI played the same scenario (see III.C.2), spoke with the same voice and said the same speech. They did not have any particular expression, no emotion, and no personality (see conclusion and perspectives).

A. Global setting

Participants were pupils in the last "level" of elementary school (average age: 10.27 years old). We choose young people to test StimCards because we wanted to check if the game was easy to use enough. Young people are not expert in computing, so they represent a big cross-section. And they do not have problems with technology, so it is a good starting point. Indeed, if children do not accept StimCards, it is not worth testing it with the elderly. This experimentation was realized by 52 children from two schools (27 girls and 25 boys).

To have the same experimental setting, the experimentation was conducted in a 1.60 meters cubic room, closed by green curtains. Green has been chosen to increase luminosity in the room and because it is bright and calming.

Children were isolated in the room. The both lateral curtains have one way mirrors to make sure the experimentation went smoothly. Fig. 5. illustrates the experimental setting. A desk and a chair were at the end of the room, back to the entrance. Two cameras filmed the interaction. The first one filmed children face. The second one filmed from head to knees in order to see legs and hands movements and general posture. A projector illuminated the room. A computer displayed the StimCards GUI. Game cards were placed in front of the computer. There were five

packages corresponding to the five difficulty levels: light-yellow, dark yellow, light-green, dark green and blue. A tactile tablet was placed in front of children. A camera was fixed in a black box, on the left of the computer. Children had to put a card in the box slit. The card was placed in front of the camera which read the barcode and treated the question. When children finished playing with a card, they throw it away in the trash box. The tested HGI was placed on the left of the computer.

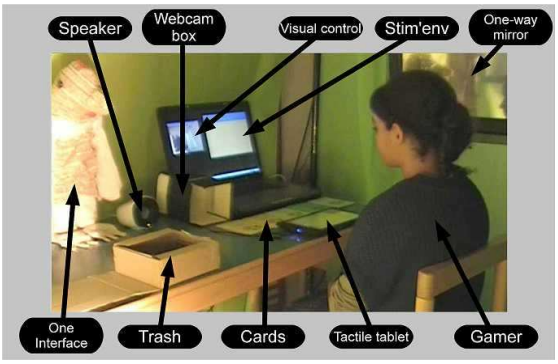

Figure 5. Experimental setting

B. Evaluation

At the end of each ten minutes game session, children had to fill a questionnaire which corresponded to 1 to 13 questions of Table II. At the end of the four sessions, they had to fill a final questionnaire which corresponded to 14 to 21 questions. The first questionnaire valued the four HGI. The second questionnaire valued StimCards. Questions 20 and 21 valued the favourite HGI.

Thus, each participant filled five questionnaires. The term "HGI" was replaced by "computer", "animal", "robot" and "character" according to the current session.

Concerning 1 to 19 questions, a Likert scale was used to answer: Strongly disagree, Disagree, Neither agree or disagree, Agree, Strongly agree. Questions 20 and 21 were free. In results study, we associate a value to these answers. 0=Strongly disagree, 1=Disagree, 2=Neither agree or disagree, 3=Agree and 4=Strongly agree. In the figures, the significance level was marked * for $p<0.05$, ** for $p<0.01$ and *** for $p<0.001$.

TABLE II. ASKED QUESTIONS

1. Did you find exercises were easy?
2. Did you find that the HGI presence helped you to answer the questions?
3. Did you enjoy playing with the HGI?
4. Did you feel encouraged by the HGI during the game?
5. Did you find the HGI was nice?
6. Did you find the HGI was irritating?
7. Would you like to have the HGI at home to help you doing your homework?
8. Do you think that the HGI can do mental arithmetic?
9. Do you think that the HGI can understand your answers?
10. Do you think that the HGI can see you?
11. Do you think that the HGI can hear you?
12. Do you think that the HGI likes you?
13. Do you think that the HGI is happy to play with you?
14. Did you enjoy playing with StimCards?
15. Would you like to have StimCards at home?
16. Were the game rules easy to understand?
17. Do you think the HGI timely spoke or move?
18. Would you like to be able to decide whenever the HGI has to make movement or to speak?
19. Would you like that the HGI was personal (adapted to you)?
20. What is your order of preference of the four HGI?
21. If you could choose a companion to help you in your daily life, which one would you choose?

C. Results

Statistical analysis were realized with Minitab 15© software. The Chi-square test determined the significant answers. The significant level (p) was equal to 0.05.

1) HGI results

From questions 1 until 13, each HGI (computer, character, robot and animal) were computed statistics. In addition, each question received a score which corresponds to a weighted sum (the value of each answer multiplied by the number of obtained votes for this answer). Thus, the highest is the score; the most positive votes are received. There are no statistical differences between the four HGI and between boys and girls. So, this paper presents the results for all HGI and without any gender distinction.

Insignificant results: Questions 2, 4 and 12 are not significant. That means children were not able to answer. These three questions deal with HGI empathic capabilities. This results show that the appearance is not sufficient to make a digital partner nice and empathic.

Significant "Strongly disagree" results: Concerning the first question, a few children judged the exercises difficult despite the growing difficulty. The majority judged the exercises easy. HGI have never been judged irritating. The majority of children think that HGI were not able to see them.

Significant "Strongly agree" results: Children enjoyed playing with the HGI and found them nice. In spite of the result about vision, children thought that the HGI were able to hear them and to do mental arithmetic. In children mind, the HGI were able to understand their answer. Moreover, children thought that the HGI were happy to play with them. They wanted to have the HGI at home.

Questionnaire study: The questionnaire statistical study did not identify the HGI which was significantly preferred by the children. We therefore counted each time the HGI had the highest score, each time the HGI had the lowest score and the score of all questions (without taking the question 6 into account because its score is negative). The animal was cited the maximum number of times and get the best score whereas the robot was cited the minimum number of times and get the worst score.

TABLE III. INTERFACES SCORE

HGI	Number of min	Number of max	Total
Computer	3	2	1450

HGI	Number of min	Number of max	Total
Character	2	3	1432
Robot	1	6	1411
Animal	7	2	**1483**

2) StimCards acceptability results

Concerning StimCards evaluation, children really enjoyed playing with it (X^2=86.8462, p=0.000, Fig. 6). They would like to have this game at home (X^2=61.8462, p=0.000, Fig. 6). The game rules were judged really easy (X^2=53.5769, Fig. 6).

Concerning the game scenario, children thought that the HGI timely spoke and move (X^2=21.2549, p=0.000, Fig. 6). The majority of children indicated that they wanted to be able to decide whenever the HGI had to make movement or to speak (X^2=31.6538, p=0.000, Fig. 6). However, this question is contrasted because the second given answer is "Strongly disagree". Finally, children wanted that the HGI were personalized (X^2=69.7308, p=0.000, Fig. 6).

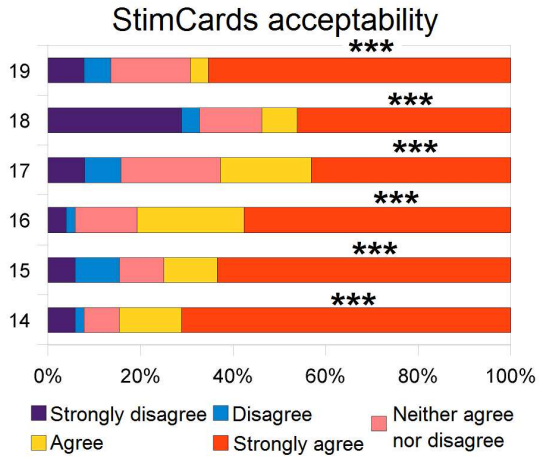

Figure 6. StimCards acceptability

3) HGI order of preference results

The order of preference given by the children indicated that the robot was the most of time cited first (46.15%, X^2=21.2308, p=0.011, Fig. 7). It was never the last. The second preferred HGI was also the robot with 36.54%, followed by the animal with 30.77%. The group Robot-Animal received 80.77% as the first position and 67.31% as the second position. The computer was significant the least cited at the second position (5.77%, X^2=11.2308, p=0.011, Fig. 7). The third preferred HGI was the character (42.31%, X^2=10.3077, p=0.016, Fig/ 8). The last preferred HGI was the computer (55.77%, X^2=33.0769, p=0.000, Fig. 7). The animal is more cited at the fourth position than at the third position with 21.15% of the votes.

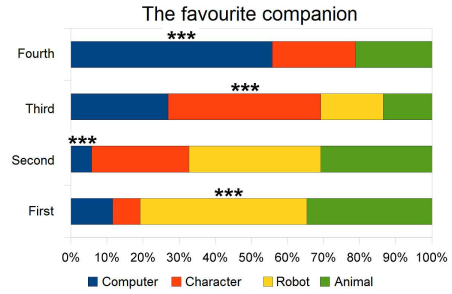

Figure 7. Companion order of preference

4) HGI chosen by children results

Concerning the choice of the favourite HGI, robot and animal had both the lead with 39.22% of the votes. The robotic system received 78.43% of the votes. The third HGI was the character with 11.76%. The last one was the computer with 9.80%. The computer was significantly the HGI which was not chosen by the children (X^2=16.5294, p=0.001, Fig. 8).

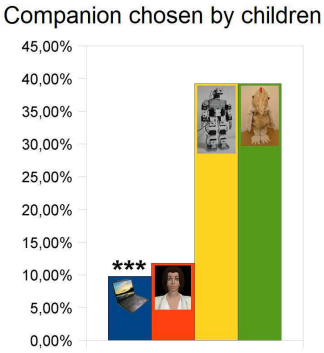

Figure 8. Companion chosen by children

Discussion: The statistical study of the questions 1-13 did not determine the preferred HGI. These questions judged it as game coordinator. The study showed that the HGI shape was not important to be liked. However, the children would surely be able to make a choice if the HGI had some character and personality. Nevertheless the animal seemed to be the most interesting for the children because it obtained the best questions score. This result was contradicted by the children order of preference. Indeed, the robot won this question. Even the last question was not able to decide between the robot and the animal, because they were tied as the first place. To conclude, there is no doubt that the robotic system is the preferred HGI because it received around 80% of the votes.

StimCards acceptability was easier to value because all of the answers were significant. StimCards is liked and accepted. All the children did not like our activity because it was mental arithmetic. However, they liked playing with the game. This result showed that StimCards can stimulate. StimCards could be a good cognitive training help for older people.

VI. Conclusion

This paper presented a new game for cognitive stimulation: StimCards. We realized experimentation with 52 children (4

sessions of 10 minutes). We tested this game with a young public and with four different interlocutors: the computer, a virtual character, a metallic robot and a plush robot. Results showed that our game is accepted by children. They really liked playing with it and found that it was easy to use. Moreover, results showed that the robot motivated children to work. Our study shows that the robot (with any appearance) is the best game partner for cognitive training.

We currently do other experimentation with old people having cognitive troubles to complete this study. We think that StimCards is an attractive game, which requires an active gamer participation. Gamers have to manipulate game cards and also to use technology in order to make questions appear and to answer them. StimCards stimulates the brain. It is not a "mouse + keyboard" applications and because it requires gamer dexterity, it avoids the passivity problem.

Perspective: we choose to test a neutral robot, which means a robot without any emotion, giving no encouragement. All digital objects (robot, animal, character and computer) pronounced the same speech with the same voice. We evaluated only appearances and the capability of objects without any other parameter. Our interest now is to experiment our game with a more emotive robot, having a personality in comparison of a neutral robot. They will both have the same appearance. It will indicate whether an empathic robot can increase the game impact.

Our final objective is to provide an efficient game which can be used in education or in cognition. It will be improved to ensure gamers progression.

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